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July 27, 1955

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The Commanding Officer
Frankford Arsenal
Philadelphia, 37, Pennsylvania

Attention: ORDBA-SP

Dear Sir:

"RESEARCH, DEVELOPMENT AND FABRICA-
TION OF CARTRIDGE, BALL, CALIBER
.35 T-117-E-1" FINAL REPORT
CONTRACT DA-19-059-ORD-1270

We submit herewith the final report on Research, Development and Fabrication of Cartridge, Ball, Caliber .35, T-117-E-1, carried out under the subject contract. The samples required under the contract were shipped to Commanding General, Frankford Arsenal, Philadelphia, Pennsylvania, Attention - J. Kirk, on June 30, 1955. Submission and acceptance of this final report together with the reproducible design drawings included in it complete the commitments of the contractor under this contract.

Yours very truly,

REMINGTON ARMS COMPANY, INC.

G. M. Calhoun
G. M. Calhoun, Director
Research and Development

RAB:jbm
att.

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CONTRACT DA-19-059-ORD-1270
FINAL REPORT

RESEARCH, DEVELOPMENT AND FABRICA-
TION OF CARTRIDGE, BALL, CALIBER
.35 T-117-E-1

July 26, 1955

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RESEARCH AND DEVELOPMENT DEPARTMENT

REMINGTON ARMS COMPANY, INC.

BRIDGEPORT, CONNECTICUT

July 20, 1955

RESEARCH, DEVELOPMENT AND FABRICATION OF CARTRIDGE,
BALL, CALIBER .35 T-117-E-1

Period: March 1953 to July 1955

Project: TD-1270-53

Notebook: No. 667

Previous Reports: AB-50-6
Contract W-19-059-ORD-3499

AB-51-19
Contract DA-19-059-ORD-12

Prepared by: Robert A. Brown

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INTRODUCTION

FINAL REPORT CONTRACT DA-19-059-ORD-1270

At the request of the Department of the Army, the Remington Arms Company, Inc. continued the development of a military cartridge suitable for use in light weight pistol. Previous work on this item has been done under Contract W-19-059-ORD-3499 and under Contract DA-19-059-ORD-12.

During Part I of the initial contract a cartridge was developed that utilized a bullet of conventional two-piece construction but having a core of zinc in place of the usual lead core. Although satisfactory from the standpoint of meeting the performance requirements of the contract, it was decided by the Department of the Army that, since zinc was on the critical materials list, it would be desirable to allocate the funds under Part II (Production Phase) of Contract W-19-059-ORD-3499 to the modification of the zinc cored bullet to a bullet having a steel core.

The funds were exhausted before a satisfactory bullet was produced and, as a result, a new contract DA-19-059-ORD-12 was negotiated to continue this work. The specifications set forth in this contract were as follows:

Caliber - not more than 9mm Parabellum, nor less than .30

Exterior Dimensions - not to exceed those of 9mm Parabellum cartridge

Accuracy - 2" group at 25 yards

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Penetration - must penetrate the M-1 helmet
at 25 yards

Priming - non-corrosive

Propellant - smokeless, flashless

Core - steel

The requirement that the core be made of steel was the only specification that had not been included in the initial contract.

As a result of the second contract, a cartridge designated T-117-E-1 was developed. It used a one piece surface decarburized steel bullet turned from SAE-1113 free machining steel. (See Exhibit 1 in the Appendix). The bullet had a nominal weight of 99 grains and a mean diameter of 0.3565" and was loaded into commercial 9mm Luger cases with 4.7 grains of Bullseye powder. A non-corrosive primer was used.

The cartridge submitted as a result of this contract averaged an extreme spread of 1.69" at 25 yards and effected complete perforation of the M-1 helmet at the same distance. It was an effective wounding instrument in that it produced a larger instantaneous wound cavity at twenty feet than the 30 caliber 150 grain military ball bullet. The cartridge developed a bullet velocity of 1266 fps. at a chamber pressure of 36,900 psi. The cartridge was interchangeable with the 9mm Parabellum round.

Several months later, after tests by the Department of the Army, the ammunition was returned to the

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Remington Arms Company, Inc. with the request that we verify the accuracy data included in the final report. By this time the 25 yard accuracy had increased from its initial value of 1.69" to 3.15". The remainder of the sample was expended in trying to determine the causes for the deterioration but without success.

On March 10, 1953 a new contract, DA-19-059-ORD-1270, was initiated which had as its prime objectives the following points:

1. Determination by the Contractor of the causes of inferior accuracy performance similar to the Contractor's recent experience with test lots of the cartridge developed under Contract No. DA-19-059-ORD-12.
2. A correction of the causes of inferior accuracy performance, if said causes are found to be due to the ammunition.
3. The necessary modification covering bullet profile to lessen damage to light alloy gun parts.
4. The provision of an adequate corrosion-resistant surface on the bullets.

OBJECTIVES

This contract had for its objectives the development of a cartridge for light weight pistol which should have, insofar as possible, the characteristics set forth in this and earlier contracts, and the delivery of 1000 rounds of the cartridge so developed to the Commanding General, Small Arms Ammunition Department, Frankford Arsenal, Philadelphia, Pa.

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SUMMARY AND CONCLUSIONS

The prime objectives of the contract have been met. The cartridge submitted as a result of the previous contract, DA-19-059-ORD-12, fired average groups of 1.69" at 25 yards at the time of submission and yet when rechecked in the same barrel ten months later, its group size had increased to 3.15". At the inception of the current contract, a lot of ammunition was made up according to the specifications outlined under contract DA-19-059-ORD-12. When fired in the test barrel used for that contract this newly fabricated sample averaged 25 yard targets of 1.38" group size. It was apparent that the deterioration of accuracy in the sample submitted for Contract DA-19-059-ORD-12 was not some flaw in testing technique but was probably caused by aging of the sample.

With this as a starting point the Metals Handbook was examined for clues. Under the section on "The Effects of Cold Work on the Properties of Iron", we find: "The mechanical properties of plastically deformed iron change with time after cold deformation, when the material is held at room temperature, and at a more rapid rate at slightly elevated temperatures." Further under the section on "Aging of Iron and Steel" we find: "Strain aging is the term applied to the changes that take place when the final operation consists of cold working. Aging may result in an increase in hardness.....".

Samples submitted under Contract DA-19-059-ORD-12 had been sized after heat treatment because the softening of the

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metal made the operation easier. This procedure apparently set the stage for the deterioration of accuracy with time as the bearing bands of the bullets strain-aged after sizing. Undecarburized SAE #1113 steel has a Diamond Pyramid hardness of 165-170 Kg/mm² in the as turned condition. Decarburization drops this hardness to a value of 120-130 Kg/mm². Measurements on bullets made as part of the first sample, Contract DA -19-059-ORD-12, showed that the hardness of the body was substantially unchanged. However, the bearing bands showed a hardness of 163 kg/mm² which is believed to account for the deterioration of accuracy with time.

For additional verification a fresh sample of SAE #1113 bullets were decarburized in moist hydrogen for two hours at 1700°F. These bullets were sized to the proper diameter and the Diamond Pyramid Hardness measured at the sized surface. Two lots of bullets were stored at elevated temperatures and it was found that the hardness of the sized area did increase with time. Presumably this is what happened with the bullets submitted under Contract DA-19-059-ORD-12. (See Exhibit 4 in the Appendix)

This has been further verified by treating identical lots of iron bullets so as to produce different surface hardnesses. Firing tests indicate that the softest surface produces the best accuracy. (See Exhibit 7 in the Appendix.)

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Further testing has indicated that it is possible to produce a softer surface with Armco ingot iron than with SAE #1113 steel and that the former will retain this softness for as long as 20 months. By sizing bullets before heat treatment rather than afterward the possibility of strain aging of the bullet bearing bands has been eliminated. Using Armco ingot iron, a redesigned cartridge, designated Cartridge, Ball, T-117-E-1 has been developed. It uses a one piece, surface decarburized iron bullet turned as shown on Exhibit 2 in the Appendix. The nose of the bullet has been redesigned to facilitate its feeding through the action of an autoloading pistol whose loading ramp is of abrupt design. Modification of the bearing bands and the use of bullet lubricants has reduced barrel wear by a factor of nearly four over that experienced with the SAE #1113 steel bullet submitted under Contract DA-19-059-ORD-12. In addition, the use of lubricants has given the iron bullet a resistance to salt spray that compares favorably with that of the brass case.

The bullet has a nominal weight of 100 grains and a mean bearing diameter of 0.3565". The bullet is loaded into 9mm Luger cases using 4.7 grains of Bullseye powder. A non-corrosive primer is used. One thousand of these rounds have been delivered to the Commanding General, Small Arms Ammunition Department, Frankford Arsenal.

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The sample submitted consisted of 700 rounds of Type A ammunition and 300 rounds of Type B ammunition. Type A ammunition demonstrates better 25 yard accuracy than Type B and in a four inch test barrel has averaged 1.35" groups for ten 10-shot targets. Its resistance to corrosion in a salt spray atmosphere (fog at 93°-98°F. with a salt concentration of 18-22%) is seven times that of unprotected Armco iron. During the test it required 225 minutes for half the sample to show surface attack.

The sample marked Type B shows accuracy inferior to Type A but is still well within the contract accuracy specification of two inches. It has averaged 25 yard groups of 1.65" when fired from a 4" test barrel. Its resistance to salt spray atmosphere is much superior to sample A since it withstood 1000 minutes before any of the sample showed signs of attack and did not reach the half way mark until 2700 minutes of test had elapsed. Thus it is 90 times as resistant to salt spray corrosion as unprotected Armco iron and 13 times as resistant as sample A. (See Exhibit 6 in Appendix).

The cartridge as loaded develops a bullet velocity of 1308 fps. at 15 feet when fired from a four inch test barrel. Under these conditions a chamber pressure of 40,200 psi is indicated when measured .500" from the face of the breech, (9mm Parabellum cartridges marked DI-44 when fired under the same conditions developed a bullet velocity 1253 fps. at a chamber pressure of 39,080 psi.

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Tests carried out by personnel of the Wound Ballistics Laboratory at the Army Chemical Center, Maryland indicate the cartridge submitted is an effective wounding instrument. Specifically, cartridge T-117-E-1 formed an average maximum instantaneous wound cavity of 303 cubic centimeters in a standard gelatin specimen. By way of comparison, the caliber .45 Ball M-1911 cartridge formed an average cavity of 130 cubic centimeters under the same conditions. A limited test on Parabellum (DI-44) cartridges performed by the Wound Ballistics Laboratory during the term of Contract DA-19-059-ORD-12 indicated an average maximum wound cavity of 152 cubic centimeters. The new cartridge appears to be twice as effective as the 9mm Parabellum cartridge and more than twice as effective as the caliber .45 Ball M-1911 cartridge.

M-1 helmets for penetration tests were not available at the completion of the contract so penetration performance data are not available. However, as reported on page 55 of the final report for Contract DA-19-059-ORD-12, "the approximate threshold of penetration of the M-1 helmet by a non-deforming steel bullet is in the region of 950 fps." Since the bullet weights are the same and since the present bullet has a pointed instead of the flat nose offered by its predecessor, there is little doubt but that the new bullet at 1308 fps. will successfully penetrate the M-1 helmet at any portion of the vital area from a distance of 25 yards.

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Ten rounds of the new cartridge have been auto-loaded through the action of a light weight pistol marked T-3 fabricated by the High Standard Manufacturing Company of New Haven, Connecticut, and used as a model arm for the development of this cartridge. These cartridges were measured for length before and after passing through the action of the pistol and it was found that the average bullet set back was 0.002".

The requirement of interchangeability between cartridge T-117-E1 and the 9mm Parabellum cartridge has been met by using a commercial standard 9mm barrel and chamber for all test work. The sole change from conventional practice has been to relocate the piston hole so that it is 0.500" from the face of the breech. The general dimensions of this barrel are as follows:

Bore diameter - .3489 + .0005" -.0000"
Groove diameter - .3580" + .0005" - .0000"
Number of grooves - Six
Width of grooves .100 + .002"
Twist - 10" R.H.
Length of barrel - 4"

A drawing of the barrel and chamber may be seen as Exhibit 3 in the Appendix.

For these reasons the new cartridge may be considered to be interchangeable with the 9mm Parabellum cartridge.

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The requirement that a smokeless, flashless propellant be used has not been completely met. Readily available powders were compared with Bullseye powder ballistically in the T-117-E-1 cartridge. Although one was found that had less flash than Bullseye powder it was not flashless. Loaded to equal chamber pressures, its use entailed a reduction of 85 fps. in velocity so it was not used in the final loading.

PATENT SITUATION

The bullet described herein and certain phases of the process of producing that bullet are believed to involve patentable novelty, and one or more patent applications will be filed. When such applications have been prepared, the usual reports will be made to the Government and copies will be made available with the filing data to facilitate the preparation by the Government of an appropriate patent licensing document.

The process outlined in this report utilizes a silicone base lubricant which was developed in Remington's commercial applications and for which Remington is seeking patent protection. Since this lubricant was not developed under this contract, appropriate license arrangements must be negotiated with Remington before an attempt is made to utilize the lubricant in other than Remington work.

The "Electroless" nickel plating process forms the subject of Patent No. 2,532,283, issuing from the work done at the Bureau of Standards, and this process may be used on

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Government work without the payment of any royalty to the inventors.

"Surf Kote" is a proprietary molybdenum disulfide lubricant and its use for its intended purpose involves no patent problems.

With the exceptions noted above, the work reported here may be duplicated without infringement of any patent noted in an appropriate patent search.

FUTURE PROGRAM

This report completes the requirements of the contract. As a result of the work carried on during this contract it is believed feasible to substitute an iron bullet for one of conventional 9mm Parabellum design should the future supply of critical materials so indicate. At that time production problems in bullet fabrication and surface treatment would need investigation. Their solution does not appear to be a difficult one.

ACKNOWLEDGMENT

The invaluable assistance of the personnel of the Wound Ballistics Laboratory, Army Chemical Center, Maryland, in evaluating the wounding potential of the T-117-E-1 cartridge is gratefully acknowledged.

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EXPERIMENTAL DETAILS

A. The Design of the Bullet

The initial steel bullet designed for use in the light weight pistol was characterized by a flat nose (see Exhibit 1 in the Appendix). This was done so as to put the center of pressure of the bullet ahead of its center of gravity. When the bullet entered a gelatin or tissue specimen the greatly increased force on the nose of the bullet made it unstable and the tumbling bullet made a very effective wounding device. This same bullet had a shearing action when it encountered the M1 helmet. The circular edge of the nose sheared a blank from the helmet just as the punch shears a blank from flat stock.

However, when the prototype model of the light weight pistol was made available it was found that the loading ramp had an abrupt rise and that it was made from aluminum. The bullet and loading ramp were completely mismatched. The latter had been designed for the long rounded nose of the Parabellum. The sharp edge of the flat nosed bullet would not feed up this abrupt ramp. The aluminum allowed this edge to dig into the ramp and a stem in loading was the usual result. The ramp soon became marked up getting a crescent shaped scar from each round.

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This early bullet was also over-designed insofar as the width of its rifling bands was concerned.

The bullet was planned to have the bullet bourrelet a close fit to the bore of the barrel so as to act as a guide to keep the bullet nose in the center of the barrel. The first rifling band was 0.025" wide and positioned to close the mouth of the case when seated to the proper depth. The second rifling band was placed 0.050" to the rear to allow a free space to accommodate the metal pulled back from the first band by the rifling of the barrel. The second band was 0.050" in sized length and then went into a boat tail which yielded further metal for engraving.

When this bullet was recovered after firing through a barrel, measurements indicated that approximately 0.073" of the rifling bands were contacted by the grooves of the barrel and 0.124" were touched by the lands. This was the bullet from which the redesign was started.

We had two objectives in the redesign. First, to modify the nose so as to feed acceptably into an abrupt loading ramp. Study of Exhibit ORD-12-12, in Appendix I of the report for Contract DA-19-059-ORD-12, was our first consideration. The original bullet's wound effectiveness came from its tumbling behavior in gelatin. Obviously shapes #7 and #10 in Exhibit ORD-12-12 were impractical from a gun feeding standpoint so it appeared impractical to design a

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tumbling bullet. Of the other three profiles, #11 was the most effective as a wounding instrument based on a nose profile. It was, of course, impractical from a gun feeding standpoint. The data indicated that the hemispherical nose of #9 was superior to the two caliber ogive represented by profile #8 from the standpoint of wounding efficiency. There was still one more consideration - that of armor penetration. Surely #9 would perforate the M-1 helmet at practical velocities but suppose this specification were toughened. A small point on the bullet would serve to concentrate its force on a small area of the armor insuring the initial rupture of the surface and penetration would undoubtedly be assured. As a result an ogive of 0.8 caliber was selected as the best compromise between a hemispherical nose and one of conventional profile.

The problem of the engraving of the bullet was given considerable thought. Iron and lead-gilding bullets were fired, recovered and examined. It became evident that we were dealing with two different mechanisms. Examination of the heel of the lead-gilding bullet showed a definite flow of lead from the land into the groove areas. The jacket acted as a plastic membrane under which the outer lead portion of the core rearranged itself in response to the pressures placed upon it. This was not so with steel. The indications were that the lands merely dragged the extra metal that they encountered to the rear

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and left it in the nearest unoccupied space. Logic indicated that the displaced metal and the land would be under high pressure until this had been accomplished.

The remedy was two-fold. First reduce the total length of the bearing band to the minimum necessary to spin the bullet under operating conditions. Second, space this band length so that displaced metal need flow a minimum distance before dropping into a relief area and reducing the bullet-barrel force.

Starting with our 0.8 caliber nose and a bourrelet diameter of 0.3485"-0.3490", the new bullet nose and the 9mm commercial luger case were laid out in a standard 9mm chamber. The front edge of the bourrelet was well entered into the chamber throat so as to minimize the jump of the bullet. The first rifling band was laid out so as to close the mouth of the case when the bullet was seated, thereby furnishing one point of contact between bullet and case. This band was made 0.010" in length which was considered a minimum dimension from a practical toolmaking standpoint.

After deciding upon a 6° taper for the heel, the second band was located so as to keep the bands as widely spaced as possible and yet allow a reasonable boat tail to aid accuracy.

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The problem of total band length was solved experimentally by reducing the band length of hand altered bullets until slippage in the barrel was indicated by recovered bullets. Then allowing some safety factor a total length of band was determined. After subtracting the 0.010" of the first band it was determined that the second band was not much more than a sharp edge at the leading end of the bullet boat tail.

Bullets with these bands were fired, recovered and measured. It was found that total length of band contacted by the grooves of the barrel was now 0.030" instead of the original 0.073". This was a reduction of 59%. Similarly, the length of the bullet touched by the bore of the gun was decreased from 0.124" to 0.086", a reduction of 31%. Thus working within our limits of cartridge interchangeability, wound ballistics, armor penetration, and tooling, we arrived at what appeared to be the best compromise.

B. Fabrication of the Bullet

All steel bullets to date have been designed with three diameters — the bourrelet, two driving bands and the under cut portions that cleared the barrel completely. Consequently only the largest diameter — the rifling bands — could be sized by passing the piece through a conventional sizing die. Other diameters required close machining tolerances. Our initial work was done on a #2 Brown and Sharpe screw machine using conventional screw machine tooling. In every case the

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the operator was asked to keep close watch on the product and attempt to hold 0.0005" variation on the diameter. However, measurement checks of the bourrelet diameters indicated that the range ran to 0.0015" with no more than 50% falling into a half thousandth class.

The use of Swiss automatic machines was investigated. In this type of machine all the turning is done by tools mounted close to the collet as the work is advanced through the collet by steps. To hold 0.0005" tolerance on the diameter, the vendor required stock that was centerless ground to 0.0001". This meant another operation.

Finally a screw machine operator suggested that we investigate the use of a shaving tool on a #2 Brown and Sharpe automatic screw machine. After considerable correspondence an order was placed with the Jersey Manufacturing Company of Elizabeth, New Jersey, for a set of forming tools cams, shaving tool and shaving tool bit to turn out the newly designed bullet. The complete cost of the tooling was \$500.50 with \$173.00 listed as the cost of the shaving tool minus its bit.

A shaving tool is similar in appearance to a heavy snap gage that is allowed to float on a pin parallel to the work piece. One anvil of the "gage" is a tool bit shaped in the contour of the piece to be shaved, while the second anvil is a free running roller. After the forming tool has shaped the work piece to within 0.002" of its final size

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it withdraws and the shaving tool advances upon the work. The roller passes across the top side of the work piece while its opposite member, the shaving bit, passes beneath the work as would be done in the action of snap gaging the diameter of the work. As the bit bears against the work it takes a shaving cut until the shaving tool can pass completely past the diameter of the work after which it is withdrawn and the work piece is cut off from the stock. In effect the operation is one of shaving to gage size simultaneously with the gaging operation.

The initial design of the shaving tool roller was faulty and the tool bit also required correction by the tool vendor. After these items had been corrected the tool could be adjusted to run satisfactory work. A check of the bourrelet diameter of 100 consecutive pieces showed that their range of diameters was 0.0005" and that 90% of the pieces were within a range of 0.0003".

It should be pointed out at this point that the shaving tool is not the answer to the entire problem. To obtain good work, the screw machine itself must be in first class condition and its collet bearings must be true and properly fitted. If this is not the case the result will be out-of-round pieces.

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In all our experimental work we have had the bullet bearing band made about .002" oversize while the bourrelet was made directly to the size desired. This permitted us to resize the bands through a range of diameters to determine the best fit to the barrel by experiment. A production bullet, of course, would be turned to final size and the sizing operation would be eliminated.

C. Heat Treatment of the Bullet

Early in the development it became apparent that the hardness of the bullet would play an important part in the functioning of the round. It was obvious that a hard bullet would wear out a barrel rapidly and it later proved that hardness was detrimental to accuracy. The work on Contract DA-19-059-ORD-12 was carried out using barrel wear and bullet accuracy data as the criteria of bullet hardness. This crude technique did not permit us to observe local changes in bullet hardness that later proved to be of importance.

Prior to the work on the current contract, the laboratory obtained a Tukon tester manufactured by the Wilson Mechancial Instrument Company of Bridgeport, Connecticut, This machine gives a measure of the surface hardness of an object by forcing a diamond pyramid point into the surface under constant load and for a fixed time interval. The impression thus made is measured microscopically and the hardness of the material determined mathematically on the Diamond Pyramid Hardness scale.

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Contrary to the Rockwell tester, which involves the thickness of the entire test piece, the Tukon tester does not record deformation of any portion of the test piece except the surface that is under direct observation. It makes unnecessary the grinding of surfaces, required by a Rockwell tester, that would have certainly destroyed the validity of the measurements that we were trying to make. In all of our tests, surfaces were measured in their natural state with no attempt made to machine the test surface to enhance the accuracy of reading the result. Occasional readings that were out of line because of surface roughness were discarded. Testing throughout was done under a light (5 kg.) load so as to confine the measurement to the outer portions of the bullet.

Decarburization is defined as the loss of carbon from the surface of the ferrous alloy as a result of heating in a medium that reacts with the carbon. We have used both tank hydrogen and dissociated ammonia as the decarburizing mediums and find no gross difference in the results. All laboratory work was done using moist tank hydrogen at 1700°F. for a period of one hour. When we first switched over to commercial heat treatment firms for our decarburization, we were unable to locate one who used tank hydrogen. Most of them make use of dissociated ammonia (25% hydrogen- 75% nitrogen) for reasons of economy. Because of the presence of nitrogen the possibility of nitriding of the surface with its hardening effect was considered. Armco iron contained none of the usual elements

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like chromium, molybdenum, vanadium or tungsten usually found in nitriding steels. It did contain some carbon but it was believed that the hydrogen present would soak out most of that. Most of the other possible combinations with nitrogen decomposed or sublimed at comparatively low temperatures or pressures.

Tests indicated that decarburization in dissociated ammonia for two hours at 1700°F. would drop the Diamond Pyramid Hardness of Armco iron from 170-180 Kg/sq.mm. to about 80-85 Kg/sq.mm. Since we had been able to obtain D.P.H. readings as low as 70 Kg/sq.mm. with laboratory decarburization in hydrogen, we assumed that the apparent difference might be caused by the difference in atmospheres. We finally were able to locate a firm that was able to supply a tank hydrogen atmosphere and had several samples done there. They were identical with those processed in dissociated ammonia. Since the difference of 15 Kg/sq.mm. found between laboratory and outside decarburizing treatments occurred on the flat portion of the hardness-accuracy curve (see Exhibit 7 in the Appendix) the difference was pursued no further and all subsequent decarburization done in dissociated ammonia.

Consideration was given to the possibility that "decarburization" of the Armco iron might in reality be simply an annealing of the material by the furnace temperature and not a result of the presence of the hydrogen.

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Samples were put through the same furnace cycle in a nitrogen atmosphere to check this. The D.P.H. obtained in this way was 106 Kg/sq.mm. and the accuracy at 25 yards not as good as decarburized bullets. Exhibit 7 in the Appendix shows the accuracy of Armco iron bullets in three states of hardness. The material as formed and without heat treatment gave a D.P.H. of 157 Kg/sq.mm. and an accuracy of 3.25". The same material after annealing had a D.P.H. of 106 Kg/sq.mm. and an accuracy of 2.20". After laboratory decarburization in hydrogen its D.P.H. was 70 Kg/sq.mm. and its group size was 1.98". The process was more than simple annealing and the hydrogen atmosphere was necessary.

D. Surface Treatment of the Bullet

One disadvantage of an iron bullet is its lack of resistance to attack by corrosive atmospheres. For instance, unprotected low carbon steel, when exposed to a warm salt vapor fog will show signs of staining in less than 10 minutes and rusting will appear in twice that time. Therefore, it was necessary to provide a protective film to enable the bullet to resist atmospheric attack.

Still a second disadvantage of an iron bullet is the fact that it must be fired from an iron barrel. In the matter of surface friction we then have similar metals rubbing against each other under high pressure. Surface temperatures are raised rapidly and the bullet tends to be

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welded to the interior of the barrel. Chamber pressure, of course, breaks it loose immediately only to have it reweld at a more distant point. These momentary welds probably occur at random during the bullet's passage through the entire barrel. This welding procedure probably contributes a good deal to the rapid wear of the barrel since, as each weld is broken, a portion of metal is probably torn from either bullet or the barrel leaving a pit in the surface of the material. Material torn from the barrel might be termed barrel wear. When the bullet is the loser, the material probably remains as a projection in the barrel to be either torn off or welded to the next bullet that passes.

Furthermore, welding that occurs at the instant the bullet exits from the barrel can be very detrimental to accuracy. This is particularly true of a weld that occurs after the bourrelet has emerged and the alignment of the bullet is preserved only by two comparatively weak, closely spaced driving bands. The impulse then imposed upon the bullet may well deflect it wide of the target. Thus we have two functions that our bullet surface treatment must fill - protection of the iron bullet against atmospheric attack and the reduction of friction between bullet and barrel.

We have not found it possible to obtain these two characteristics in maximum degree in a single surface treatment. As a consequence, several treatments that supplement each other have been devised.

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After several unsuccessful experiments using a Bonderite surface treatment of the iron with a wax filling of the pores so created, we were successful in improving bullet accuracy by the application of a patented finish called electrofilm Lube-Lok furnished by the Pyrene Metal Finishers Inc. of Newark, New Jersey. Limited tests indicated that a 30% reduction in target size could be obtained by means of a properly applied film of Lube-Lok finish.

Meanwhile our literature investigation had turned up several references that dealt with friction at high sliding velocities. They are listed below:

NACA Technical Note No. 1442

"Friction at High Sliding Velocities" by R. L. Johnson,
M. W. Swikert and E. E. Bisson

NACA Technical Note No. 1578

"Friction of Solid Films on Steel at High Sliding Velocities"
by R. L. Johnson, D. Godfrey and E. E. Bisson

NACA Technical Note No. 2628

"Bonding of Molybdenum Disulfide to Various Materials
to form a Solid Lubricating Film"

Part I - "The Bonding Mechanism" by D. Godfrey and
E. E. Bisson

NACA Technical Note No. 2802

"Bonding of Molybdenum Disulfide to Various Materials
to Form a Solid Lubricating Film"

Part II "Friction and Endurance Characteristics of
Films by Practical Methods" by D. Godfrey and
E. E. Bisson

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Generally speaking the greatest success in the reduction of friction reported in the above literature had been achieved when a tenacious film of molybdenum disulfide had been applied to the test surface. However, their testing had been done at velocities up to only 130 fps. and with comparatively light loads. Both our velocity and loading were much greater than theirs.

About this time we encountered difficulties in obtaining delivery and uniform sample films from the vendor of Lube-Lok films and decided to investigate other similar finishes. A series of finishes named Surf-Kote manufactured by the Hohman Plating and Manufacturing Company, Inc. of Dayton, Ohio came to our attention. Their formula H-205 was of particular interest to us since its optimum operating temperature was listed as 950°F. A sample of the material was obtained and experiments started.

It was found that a dip finish in H-205 did not produce a very thick film. A method was worked out whereby the bullet was spun on a magnetic chuck while the diluted finish was sprayed on it from an external mix spray gun. Stock H-205 material was diluted by the addition of 2-1/2 parts of Toluene as a thinner. The particles of the emulsion tend to settle out unless the container is agitated frequently. In order to increase the thickness of the film obtained, bullets are pre-warmed to about 130-140°F. before spraying. After air drying they were baked for two hours at 600°F.

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When bullets treated in this way were compared for 25 yard accuracy with bullets without Surf-Kote the difference was significant. Untreated bullets averaged a group size of 2.34" while those finished with Surf-Kote H-205 averaged 1.36".

However, when exposed to salt vapor fog at 95°F. the resistance of the coated bullets was only slightly better than uncoated samples. While the friction problem had been solved, the corrosion problem had not.

Our next problem was to obtain a corrosion resistant film that could be used in conjunction with Surf-Kote and which would not have an adverse effect on bullet accuracy. A flash electro-plate of copper was applied over the iron bullet. This improved corrosion resistance to some extent but brought up another difficulty. During the electrolytic plating of copper, hydrogen is evolved. This probably occurs in the nascent or atomic form and later combines with other atoms to form the molecular gas that is evolved. In any case it could be shown that the electroplating of copper on the iron bullet is just about doubled in hardness when measured with a Diamond Pyramid indenter on a Tukon hardness tester. Thus it appeared that protection by electroplating was not open to us.

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About that time an article in the publication "Plating" for November, 1954, was brought to our attention. It was entitled "A Practical Application of Electroless Nickel Plating" and was written by J. D. MacLean and S. M. Karten. In substance it was pointed out that the electroplating of deep, blind holes has always been a problem because of the distortion of the electric field by the geometry of the setup. It suggested electroless plating as a substitute since the metal was plated out equally on all surfaces touched by the solution. Our problem was not one of plating blind holes, but plating without the release of hydrogen might solve our problem. Of course, it was known that nickel as a bullet jacket did not give good accuracy, but it was worth a try.

The process for carrying on the plating called for the prior preparation of four solutions:

1. Initial Plating Solution

Nickel chloride - $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$	6.0 oz./gal.
Ammonium chloride - NH_4Cl	6.7 oz./gal.
Sodium citrate - $\text{Na}_3\text{C}_6\text{H}_5\text{O}_7 \cdot 5\text{H}_2\text{O}$	13.4 oz./gal.
dissolve in water and filter	

2. Replenisher for plating solution

Nickel chloride	20.0 oz./gal.
Ammonium chloride	2.0 oz./gal.
Sodium citrate	6.0 oz./gal.
dissolve in water and filter	

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3. Hypophosphite solution

Sodium hypophosphite $\text{NaH}_2\text{PO}_2 \cdot 5\text{H}_2\text{O}$ 60.0 oz./gal.
dissolve in water and filter

4. Ammonia solution

One part concentrated ammonia water diluted
with two parts distilled water

Our laboratory people varied the procedure somewhat from that stated in the article. Our procedure was as follows:

The plating solution was heated to 206-210°F. and three fluid ounces per gallon of the hypophosphite solution added. The ammonia solution was added until the solution showed its first permanent blue color (P.H. between 8.5 and 9.0). The work is then suspended in the plating solution in a non-metallic basket so that the basket does not also plate out the nickel. When the plating is proceeding satisfactorily, the solution gases moderately. The nickel that plates out of solution is replaced by adding replenishing solution to the point where a white precipitate begins to form. Since hypophosphite is also used up, it must be replaced by addition of its solution. Slow gassing indicates the need for more hypophosphite while excess hypophosphite will cause violent gassing which may precipitate all of the nickel in the solution and is to be avoided. An excess of ammonia will boil off. Our experience indicates that if the plating solution is kept balanced, 0.0004"-0.0005" of nickel will be plated out per hour. The work in the

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basket should be agitated periodically to avoid voids where pieces touch each other or the basket.

Armco iron test pieces nickel plated by this process showed a 50% resistance to salt spray corrosion of about 160 minutes which compared with 22 minutes for the unplated material. As had been expected, nickel plated bullets shot poorly until they were given a salt spray finish of Surf-Kote H-205 followed by the usual two hour bake at 600°F. This improved their accuracy and average targets of 1.60" to 1.70" could be expected in comparison with the 1.30" - 1.40" obtained with unplated but Surf-Koted Armco iron.

Other members of the laboratory had been working with Dow Corning Silicone fluids as bullet lubricants. One of their samples was an experimental fluid known as XF-4050 which had been developed as an aircraft gas turbine lubricant. It was designed to provide lubricity for steel to steel contacts at high temperatures. It was suggested that it might be of value in our problem. Limited tests indicated that, when it was wiped on bullets at full strength, it did improve bullet accuracy. Specifically, Surf-Koted nickel plated Armco bullets averaged groups of 1.60" while the same bullets wiped with XF-4050 averaged groups of 0.95". However, XF-4050 at room temperature has a viscosity of 21 centistokes - about the viscosity of a thin machine oil at room temperature. The problem of adherence to the bullet was met by blending it half and half with Ozokerite which yielded a practical wax bullet lubricant.

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It is applied over the case mouth to loaded rounds by dipping the cartridge, nose down, into the molten mixture. The lubricant is kept between 210-240°F. and the bullets are immersed for 60 seconds for thorough heating before withdrawal from the lubricant. Then the bullet nose drop is touched off on a cloth pad and bullets allowed to cool nose up. This places a fillet of wax at the case mouth to further insure moisture proofing of the powder charge.

Although the blended mixture has not shown the improvement in accuracy that was hoped for, its resistance to salt spray corrosion has been well worth its addition. For instance the 50% corrosion time of Surf-Koted Armco bullets has been raised from 30 minutes to 230 minutes by the silicone-ozokerite lubricant - an improvement of 700%. Armco bullets with nickel plate plus Surf-Kote films have had their resistance raised by over 1600% or from 155 minutes to over 45 hours by the use of the wax lubricant.

Two tests have been performed on samples of the blended lubricant. The first is an adaptation of A.S.T.M. test D-556-42 "Dropping Point of Lubricating Grease". In this case the cool bulb of a mercury thermometer is dipped into the melted lubricant and withdrawn immediately with a congealed film of wax. The thermometer is placed in an oven whose temperature is raised slowly. When the wax melts sufficiently to drop a drop from the bulb, the reading of the thermometer is noted as the dropping point. The XF-4050-Ozokerite blend has a drop point of 173°F.

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Another bullet lubricant characteristic that is of interest in the ammunition industry is the running point of a lubricant. This relative measurement determines how quickly a bullet lubricant may migrate into the powder under elevated storage conditions. In this case a 1/4" pellet of the wax is placed on a filter paper in a 130°F. oven for 30 minutes. The wax lubricant used on the T-117-E-1 cartridge was subjected to this test and its resultant grease spot was 1/2" in diameter. In this test a resultant grease spot of 1" diameter is not considered excessive.

Thus it is felt that the problem of the salt spray resistance of iron bullets has been successfully met.

Bullets protected against corrosion by the use of different surface treatments were exposed to the corrosive effect of a brine fog containing 18-22% salt at a temperature of 93°F.-98°F. They were inspected at regular intervals and a bullet was said to have failed the test when the first tiny speck of rust could be observed on its surface. This did not mean that the bullet was beyond use since rusting usually begins at the nose and spreads to the bourrelet last of all.

Photographs were taken of T-117-E-1 Type A and Type B cartridges after 20 hours and 70 hours exposure to this corrosive atmosphere. These photographs appear under Exhibit 5 in the Appendix. Type B samples incorporating a nickel plate are shown in the top row. The first bullet

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in this sample showed attack after 1100 minutes of exposure while the last bullet did not show attack until 4300 minutes had elapsed. Type A samples (without nickel plate) are shown in the second row. In this case the first bullet showed attack in 190 minutes with the last bullet showing its first rust spot in 340 minutes. The bottom row of bullets in the photographs are unprotected Armco iron. In this case the initial attack occurred in 10 minutes with the last bullet showing a rust spot after 45 minutes.

A plot of the resistance life of these three samples together with other possible finishes appears in Exhibit 6 in the Appendix. From this graph the 50% protection time can be determined.

E. Accuracy of the Cartridge

There are many characteristics of a bullet that affect its accuracy. In addition to all the usual factors of aerodynamic design, bullet launch, and bullet spin that influence the accuracy of all bullets, iron bullets are sensitive to such factors as contact area with the barrel, hardness of the bullet, and treatment of the bullet's surface. An ideal iron bullet should have the following general characteristics:

1. Most of the bullet should have a diameter appreciably smaller than the bore of the gun through which it is to be fired. Only sufficient bullet material should contact the barrel to maintain the

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bullet's alignment during its passage through the bore. These supporting rifling bands should be as narrow as practicable and be followed by relieved portions that are several times the length of the preceding band. The bands should be located near the ends of the bullet to lengthen the alignment base of the latter.

2. The bullet material should be of such type that heat or other treatment will bring its Diamond Pyramid Hardness (5 kg. load) below 100. Values in the 70's or lower are even better. There appears to be good correlation between iron bullet hardness and accuracy as shown by the graph in Exhibit 7, in the Appendix. The bullet material must be so selected and so handled that its hardness does not tend to increase with time.
3. Since an iron bullet is to be fired through a barrel of similar material, we encounter an unfavorable bearing situation. We have two similar materials rubbing together and they tend to gall or sieze instead of sliding easily over each other. The introduction of a dissimilar material into this bearing is practically a necessity.
4. Despite its many useful characteristics, iron is subject to surface attack by the atmosphere and must be protected against such contact if it is to be a useful service material. For instance, Johnson, Godfrey and Bisson report in their paper on "Friction of Solid Films on Steel at High Sliding Velocities" that the presence of ferric oxide on steel is detrimental to friction and wear of the surfaces. Poor friction characteristics lead to high contact temperatures and the momentary welding that is detrimental to barrel wear and bullet accuracy. Therefore a corrosion resistant finish must be supplied.

The reasons for the size and location of the bullet bearing bands are comparatively self-evident. Referring to the sketch of the bullet on page 2 in the Appendix, we note three bearing bands on the bullet. The one nearest the nose is broad for strength but its diameter is kept close to bore size to reduce friction with the lands. This bourrelet serves

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to keep the fore portion of the bullet aligned with the bore of the barrel. The second and third bands are comparatively short in length and of sufficient diameter to engage the grooves of the barrel. This engagement imparts the spin to the bullet. The middle band is located so that it just closes the mouth of the case when seated to the proper depth. In conjunction with the rear band it also serves to insure axial alignment between the bullet and the case of the loaded round. The rear band has been given a taper originating at the heel and terminating in a sharp edge at the forward side. Its function is to form a seal for the powder chamber as well as align the bullet in the case. Its taper heel makes it possible to seat bullets in cases without using a mouth opening punch during the loading operation. Since the case mouth is not opened prior to loading, there is no need to crimp the case mouth after bullet seating, thus eliminating two stations in the loading operation. The rear band entering the case mouth stretches the case slightly and the forward sharp edge on this band serves to lock the bullet to the case in such a way that bullet setback in an autoloading pistol is only 0.002" per cycle. Should a tighter crimp be desired, a light rolling crimp of the case mouth would serve to lock the case even more tightly to the bullet.

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We have selected Armco ingot iron as our bullet material for several reasons. First, its low carbon content makes it less subject to atmospheric corrosion than the SAE #1113 free machining steel with its 11 points of carbon. Two, although its Diamond Pyramid Hardness in the as drawn state was the same as SAE #1113 steel, it was found that a decarburizing heat treatment softened Armco iron to the region of 70-80 Kg/sq.mm. (D.P.H.) while SAE #1113 could not be brought below a D.P.H. of 115 Kg/sq.mm. Furthermore test pieces have indicated that Armco iron will retain its soft skin for as long as 19 months if it is not cold worked during the period. Here was a material that could be made comparatively soft and appeared to retain this softness for an appreciable time.

The problem of galling between two iron surfaces was solved by the use of a Surf-Kote H-205 film on the bullet. This reduced average group size by approximately one inch.

Bullet corrosion was met by the combined use of a 0.0005" electroless plating of nickel and a blend of silicone-ozokerite wax lubricant. The nickel is known to be detrimental to accuracy but its combination with the wax lubricant gives steel an exceptionally high resistance to salt spray corrosion.

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The silicone fraction of the lubricant is known to aid bullet accuracy when used full strength but it is too thin to be used alone and must be blended with ozokerite to give it a usable body. It is possible that the Dow Corning Corporation may be able to formulate this material with enough viscosity to make full strength use practicable. Increased accuracy should result.

The final accuracy evaluation of the T-117-E-1 Type A cartridge was performed in a four inch barrel mounted in a machine rest. Ten shot targets were taken at 25 yards. A second paper at the same position was used to measure 50 shot composite targets on the same ammunition. The results of the ten 10-shot target test are listed below:

Ammunition: T-117-E-1 (Type A)

Barrel - Four inch test barrel (drawing on
Exhibit 3 in the Appendix)

Distance - 25 yards

<u>Target No.</u>	<u>Group Size*</u>
1	1.65
2	1.10
3	1.30
4	1.25
5	1.08
6	1.70
7	1.35
8	1.63
9	1.15
10	1.20

Average group size - 1.34"
Maximum group size - 1.70"
Minimum group size - 1.08"

* Group size for this report is defined as the diameter of the smallest circle that will encompass the centers of the bullet holes in the target.

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When the 50 shot composite targets were scored it was found that the first 50 rounds had a group size of 1.70" while the second 50 rounds were contained in a circle that was 2.10" in diameter.

A reproduction of these targets may be found in Exhibits 8 and 9 in the Appendix. The two inch circle surrounding each group represents the average accuracy specification for the contract.

Fifty rounds of 9mm Parabellum (DI-44) cartridges were fired in groups of 10 through the same barrel for 25 yard targets. A composite target of 50 rounds was taken at the same distance. The results follow:

Ammunition - 9mm Parabellum (DI-44)

Barrel - Four inch test barrel (drawing
in Exhibit 3 of the Appendix)

Distance - 25 yards

<u>Target No.</u>	<u>Group Size</u>
1	2.50"
2	1.28"
3	1.80"
4	1.88"
5	2.12"

Average group size - 1.92"
Maximum group size - 2.50"
Minimum group size - 1.28"

The fifty shot composite target of 9mm Parabellum (DI-44) cartridges indicated a group size of 2.65". A reproduction of this target is shown as Exhibit 10 in the Appendix.

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As an indication of the accuracy that may be expected of the T-117-E-1 cartridge when fired from a longer barrel, two 10-shot groups were fired through a 7-1/2" test barrel and targets were recorded at 25 yards. One of these groups could be fitted into a 0.62" circle while the second could be contained in a 0.50" circle. Their average group size is 0.56".

It is apparent that the high velocity of the T-117-E-1 cartridge in the 4 inch barrel is attained only through high muzzle pressure. This gas flow at bullet exit tends to cause yaw. When fired through the longer (7-1/2") barrel, muzzle pressure is reduced and a very accurate cartridge is the result.

No accuracy data were taken on the final loading of the type B (nickel plated), T-117-E-1 cartridge. However, experience indicates that an increase in average group size of .25 to .30 of an inch can be expected because of the presence of the corrosion resistant nickel plate used on this bullet.

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F. Ballistics of the Cartridge

The experimental ballistics work done on the cartridge has been limited to an evaluation of the performance of Western Ball 460-A powder. It had been noted visually in the past that the Ball type powders did not give as much muzzle flash with the experimental cartridges as did Bullseye powder. Since reduced muzzle flash was an objective of the contract, an experiment was performed to determine the ballistics of Western Ball powder when used in the T-117-E-1 cartridge. Charge weights of 4.3 grs., 4.5 grs., and 4.7 grs. of Western Ball 460-A powder were loaded into commercial Luger cases using Armco iron bullets of the type used in the final cartridge. Over-all cartridge length was set at $1.125" \pm .005"$. No crimp was used. Cartridges were fired from a 4" test barrel with the center of the 0.206" pressure piston located 0.500" from the breech face. Copper crushers measuring .225" x .500" were used to measure the chamber pressure and bullet velocity was measured over a 20 ft. interval centered 15 ft. from the muzzle.

The results indicated that a change from Bullseye to Western Ball powder required that we accept an 85 fps. loss in velocity when loading to the same chamber pressure. This was undesirable since we needed maximum velocity to maintain the wounding effectiveness of the cartridges. (Redesigning from a tumbling to a stable bullet had already cost us effectiveness in this field.) Since wound ballistic cavity volume is believed to depend on the term v^n where v is the velocity of the bullet and n

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appears to lie between 2 and 3, an 85 fps. loss in velocity was not to be considered lightly. To maintain the velocity of the bullet and use Western Ball powder meant that we must allow maximum chamber pressure to rise 6,000 psi above that set for the 9mm Parabellum cartridge. This, of course, was impractical so Bullseye powder was continued as the propellant for the T-117-E-1 cartridge.

The final T-117-E-1 cartridge was loaded in 9mm commercial Luger cases in which non-corrosive primer is used. Cases were primer waterproofed with lacquer and mouth sealed with the usual military varnish. The case mouth was further sealed by an over-the-mouth dip into the bullet wax lubricant (50% XF-4050, 50% Ozokerite) mentioned in the section on Surface Treatment of the Bullet. Thus the powder of the cartridge is well sealed against moisture.

Twenty rounds of the cartridge were fired for chamber pressure and 20 more for long piston velocity. Twenty rounds of 9mm Parabellum D.I.-44 cartridges were also fired for pressure. A drawing of the 4" test barrel used in this test is included in the Appendix as Exhibit 3. The results of these tests are as follows:

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Cartridge, Ball, Caliber .35 (T-117-E-1)

	<u>Velocity*</u> <u>Short Piston</u> <u>fps.</u>	<u>Pressure**</u> <u>psi</u>	<u>Velocity*</u> <u>Long Piston</u> <u>fps.</u>
Average	1286	40,205	1308
Maximum	1300	42,500	1333
Minimum	1269	37,000	1288
Ext. Var.	31	5,500	45

* Measured at 15 ft. from the muzzle over an interval of 20 feet

** Measured in the chamber 0.500" from the breech face

Cartridge, Ball, 9mm Parabellum DI-44

	<u>Velocity*</u> <u>Short Piston</u> <u>fps.</u>	<u>Pressure**</u> <u>psi</u>
Average	1254	39,085
Maximum	1280	44,800
Minimum	1222	33,500
Ext. Var.	58	11,300

* Measured at 15 ft. from the muzzle over an interval of 20 feet

** Measured in the chamber 0.500" from the breech face

It should be noted that although the average chamber pressure of T-117-E-1 cartridge is slightly higher than that measured for the 9mm Parabellum, it has a smaller extreme variation and its maximum pressure was 2000 psi lower than the maximum pressure measured for the latter.

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It has been recently brought to our attention that 9mm Parabellum cartridge velocity is sometimes measured in a 7-1/2" test barrel. Accordingly we have had a 7-1/2" test barrel made up. Its dimensions and chamber are identical with the 4" barrel used for other ballistic tests. Its only difference is the fact that its barrel is 7-1/2" long (including chamber). Ten round tests of T-117-E-1 cartridges and 9mm Parabellum cartridges were fired through this long barrel and the long piston velocity of the cartridges was measured at 15 ft. from the muzzle over an interval of 20 ft. The results follow:

Long Piston Velocity at 15 Ft. over 20 Ft.

	<u>T-117-E-1</u> <u>fps.</u>	<u>9mm Parabellum DI-44</u> <u>fps.</u>
Average	1378	1413
Maximum	1414	1438
Minimum	1364	1380
Ext. Var.	50	58

The specifications of the test barrels used throughout the ballistics work reported here are as follows:

Bore Diameter - .3480"	Twist - 10" R.H.
Groove Diameter - .3580"	Length of Barrel - 4" or 7-1/2" as noted
No. of Grooves - 6	Diameter of Piston - .206"
Width of Grooves - .120" + .002"	

All tolerances + .0005" except as otherwise given.

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G. Wound Ballistics of the Cartridge

As explained in the section under Design of the Bullet, the wounding ability of the steel bullet submitted under Contract DA-19-059-ORD-12 was based on a bullet design that was unstable in the gelatin test specimen (simulated tissue). The flat nose of the bullet was basic for this performance, Since this flat nose caused gun damage and chamber stems in the prototype weapon, the current contract had, as one provision, a redesign of the bullet so as to eliminate these difficulties. As also explained in the section on bullet design, this redesign called for a shift in wound ballistics planning from a bullet that tumbled in tissue to one that was stable in tissue and that gained its effectiveness only from its velocity. Therefore the profile of the new bullet was selected as the best compromise between loading in the gun, armor penetration and a stable bullet but one that was still effective as a wounding mechanism.

A sample of 50 rounds of the Cartridge, Ball, Caliber .35 T-117-E-1 sample were forwarded to the Wound Ballistics Laboratory at the Army Chemical Center, Maryland, with the request that they determine the effectiveness of the cartridge as a wounding instrument. A subsequent visit was made to discuss the results of the test with Dr. A. J. Dziemian, Chief, Wound Ballistics Branch. During this meeting our earlier understanding that the maximum instantaneous cavity made in a standard gelatin specimen by a bullet was still the best measure of its wounding effectiveness was reaffirmed.

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The Wound Ballistics Laboratory had fired a number of these new steel bullets through gelatin specimens and had taken microsecond roentgenograms of the cavity as it appeared during different phases of its life. The same experiment had been done with a number of caliber .45 Ball M-1911 cartridges. When the results of the tests were plotted on the basis of cavity volume vs. time after impact, the following conclusions could be drawn. The T-117-E-1 cartridge formed a maximum instantaneous cavity volume of 303 cubic centimeters. This volume was reached about 1800 microseconds after impact. By way of comparison, the caliber .45 Ball cartridges formed a maximum instantaneous cavity of 130 cubic centimeters and attained this size 1500 microseconds after impact. Thus it would appear that the T-117-E-1 cartridge is 2.3 times as effective as the caliber .45 Ball M-1911 cartridge when both bullets are fired at their design velocity. A tentative estimate indicates that if both bullets were fired at the same impact velocity, the caliber .45 Ball would show the larger cavity. This is to be expected because of its larger cross-sectional area and because its hemispherical nose is slightly more effective than our ogive profile. We, of course, used a modified hemispherical profile to enhance armor penetration and rely on our higher impact velocity to make up the difference due to less effective nose profile.

A copy of the Wound Ballistics Laboratory report appears in the Appendix as Exhibit 11.

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9mm Parabellum cartridges were not fired during the current testing program. However, during the wound ballistics testing on Contract DA-19-059-ORD-12, three rounds of 9mm Parabellum cartridges were tested with the results indicated on Exhibit ORD-12-13 in the final report of the contract. The average impact velocity of the three shots fired was 1215 fps. and the average instantaneous maximum cavity was 152 cubic centimeters. Based on these data, the T-117-E-1 cartridge appears to have twice the effectiveness of the 9mm Parabellum cartridge.

In closing this section it should be pointed out that a solid bullet that is stable in gelatin will probably never be as effective a wounding instrument as one designed to tumble under the same conditions. An increase of 50% in cavity volume can be obtained by utilizing the tumbling mechanism. It may be possible to design a gun that will handle flat nosed bullets to take advantage of this fact.

H. Armor Penetration of the Cartridge

After the development of the final T-117-E-1 cartridge, M-1 helmets to check its armor penetration could not be conveniently procured. Consequently such data on the current cartridge are not available. However, during the experimental work carried on during Contract DA-19-059-ORD-12 it was determined that the minimum velocity needed by a non-deforming steel bullet for penetration of the M-1 helmet was approximately 950 fps. (see page 55 of final report)

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The average velocity of the new cartridge measured 20 feet from the muzzle is 1308 fps. Using this figure and a calculated ballistic coefficient for the bullet, its velocity as a function of range has been calculated. This plot appears in the Appendix as Exhibit 13. From the graph it can be seen that its average velocity at 25 yards is about 1190 fps. and that its range of penetration of the M-1 helmet is greater than 75 yards.

I. Barrel Wear of the Cartridge

Time and materials for an extensive barrel wear test of the T-117-E-1 cartridge were not available at the termination of the contract. However, several changes were made in the bullet during its development that should increase the life of the barrel with which it is used.

First, the length of the bullet that contacts the lands of the barrel was reduced from an average of 0.124" to 0.086" by redesigning the bearing bands. This reduction of 31% in contact area should reduce wear of the barrel. Similarly, the length of the bullet contacting the grooves was reduced from 0.073" to 0.030" - a reduction of nearly 60%. This reduction in the length of the bearing bands also permits metal displaced by the lands to drop into a region of low contact pressure sooner than could be expected with longer rifling bands. The net result is less metal to metal contact and an earlier reduction in engraving pressure as the bullet passes through the barrel.

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Second, two methods of reducing barrel-bullet friction have been employed in the surface treatments of the iron bullets. Examination of test barrels used with early steel bullets, where barrel life was short, show a characteristic rippled finish on the surface of the lands. It is thought that this could be explained by a stick-slip passage of the bullet through the barrel as might be expected if the bullet were to weld momentarily and at random to the barrel during its passage. This welding would be expected between similar metals moved relative to each other under high velocity and bearing pressure. To reduce this friction the bullets have been given a baked-on film of Surf-Kote H-205. Its chief anti-friction component is believed to be molybdenum disulfide which other experimenters have found effective in reducing friction of this type. The inclusion of Dow Corning fluid XF-4050 in the wax lubricant is believed to help reduce friction although proof of this is not conclusive.

(The Dow Corning reference 3-305, January 1955, on Dow Corning XF-4050 Fluid shown as Exhibit 14 in the Appendix indicated that the material was developed as a steel to steel lubricant for use in aircraft gas turbine engines). Combining these surface treatments should reduce the bullet-barrel tendency toward welding and thereby reduce wear of the barrel.

It is interesting to note that barrels used with surface treated bullets show little if any appearance of the rippled lands experienced with unlubricated steel bullets. A small amount of barrel wear data with surface treated bullets is available.

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A new 4" test barrel was air gaged for land and groove diameters at intervals of 1/2" starting at 1" from the breech face. A total of 160 rounds of T-117-E-1 cartridges were fired through the barrel after which it was remeasured. The only dimension to change significantly in this time was the average diameter of the lands at one inch from the breech face. This dimension had increased 0.0004" in 160 rounds for an average land wear of 0.00025" per 100 rounds. Referring to Appendix I of the final report for Contract DA-19-059-ORD-12 in Exhibit ORD-12-4 we note that the wear per hundred rounds for decarburized SAE #1113 steel (broad rifling bands) bullets was 0.0010" per hundred rounds at the same station. It would appear that the new bullet design with its surface treatment had reduced barrel wear by a factor of 4 over the earlier bullet. Referring to Exhibit ORD-12-7 in the same appendix we note that the indicated wear for 9mm Parabellum bullets at the same station is 0.0002" per hundred rounds. This appears to be only slightly better than the 0.00025" wear per hundred rounds found for the T-117-E-1 cartridge. Further wear tests are indicated.

J. Gun Functioning Test of the Cartridge

Ten rounds of the T-117-E-1 cartridge have been successfully autoloaded into the chamber of High Standard Manufacturing Company prototype pistol marked T-3. In each case the round was loaded by firing a 9mm Parabellum cartridge from the chamber of the weapon. In each case the overall length

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of the new cartridge was measured before it was placed in the magazine and again after autoloading when it was removed unfired from the chamber. The average bullet setback for 10 rounds was 0.002". The maximum setback recorded was 0.0045", while the minimum was 0.001".

When the rounds were visually examined after the test they appeared to have followed a regular pattern in the loading cycle. In each case there appeared to have been a double contact with the loading ramp and single contact with the barrel extension. It is believed that the T-117-E-1 cartridge will cause no more damage to the loading ramp of the pistol than can be expected from the 9mm Parabellum cartridge.

RABrown:jbm

7-26-55

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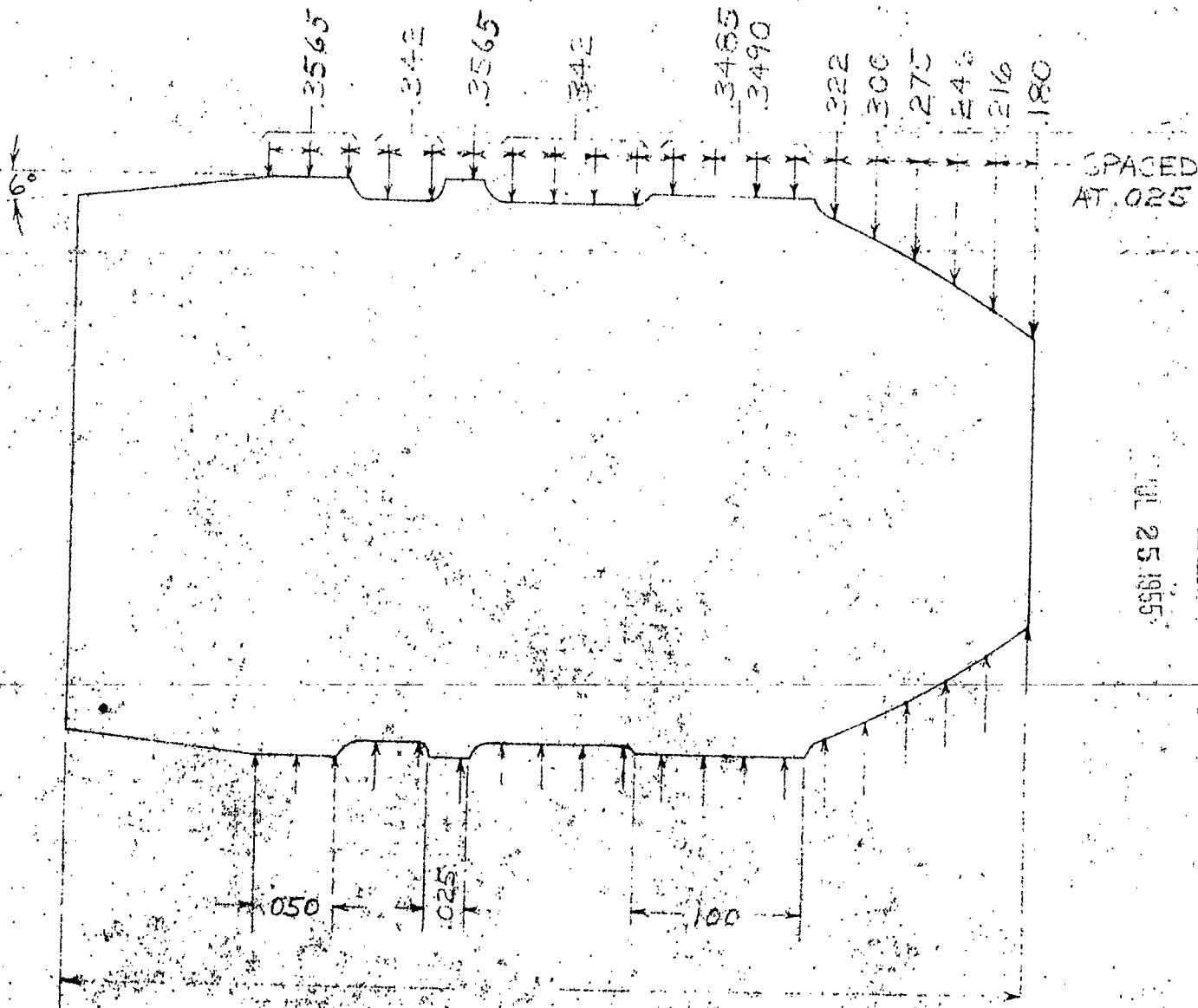
APPENDIX

<u>TITLE</u>	<u>EXHIBIT</u>
Experimental Bullet #13-E	1
Bullet for Cartridge, Ball, Cal. .35 T-117-E-1	2
Standard Barrel for Cartridge, Ball, Cal. .35 T-117-E-1	3
The Effect of Sizing on the Diamond Pyramid Hardness of Decarburized SAE #1113 Steel Aged at Elevated Temperatures	4
Photographs of Final Cartridges after 20 hours and 70 hours of Exposure to Warm Salt Fog	5
Salt Spray Resistance of Several Bullet Finishes	6
Bullet Hardness vs. Accuracy at 25 Yards	7
Accuracy of Cartridge, Ball, Cal. .35 T-117-E-1 at 25 Yards (10 shot targets)	8
Accuracy of Cartridge, Ball, Cal. .35, T-117-E-1 at 25 Yards (50 shot targets)	9
Accuracy of Cartridge, Ball, 9mm Parabellum DI-44. (50 shot targets)	10
Report on (Wound Ballistics of) .35 Cal. Ball Cartridge T-117-E-1	11
Calculated Velocity Vs. Range, Cartridge, Ball, Cal. 35 T-117-E-1	12
Preliminary Data on Dow Corning F-4050 Fluid	13

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EXHIBIT I

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FORMING TOOL #13
MATERIAL SAE #1113 STEEL

REMINGTON ARMS CO., INC. - BPT., CONN.
TECHNICAL DEPARTMENT

EXPERIMENTAL BULLET #13-E

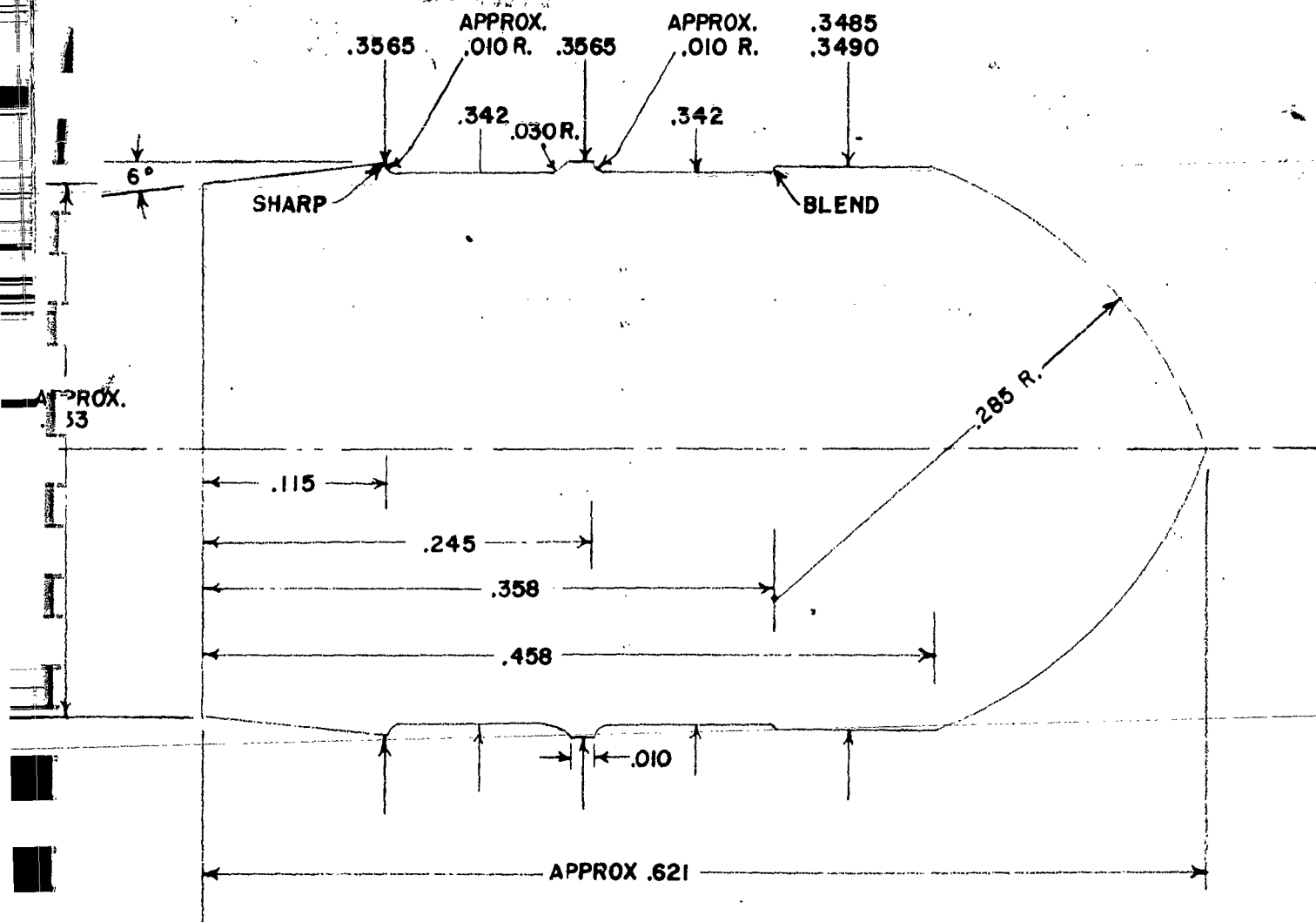
DRAWN BY: R. BROWN DATE: 9-27-51

SKRL-10-851-3

M-B-7-1555-1

R. D. 979-100

EXHIBIT 2



FORMING TOOL NO. 14 WITH SHAVING CUTTER

MATERIAL- ARMCO INGOT IRON BULLET WEIGHT - 100 GR.

HEAT TREATMENT- TWO HOURS IN DISSOCIATED AMMONIA AT 1700° F.
or
ONE HOUR IN MOIST TANK HYDROGEN AT 1700° F.

SURFACE TREATMENT

TYPE A

TYPE B

.0005" ELECTROLESS
NICKEL

SURF KOTE H-205

SURF KOTE H-205

TWO HOUR BAKE 600°F. TWO HOUR BAKE 600°F.

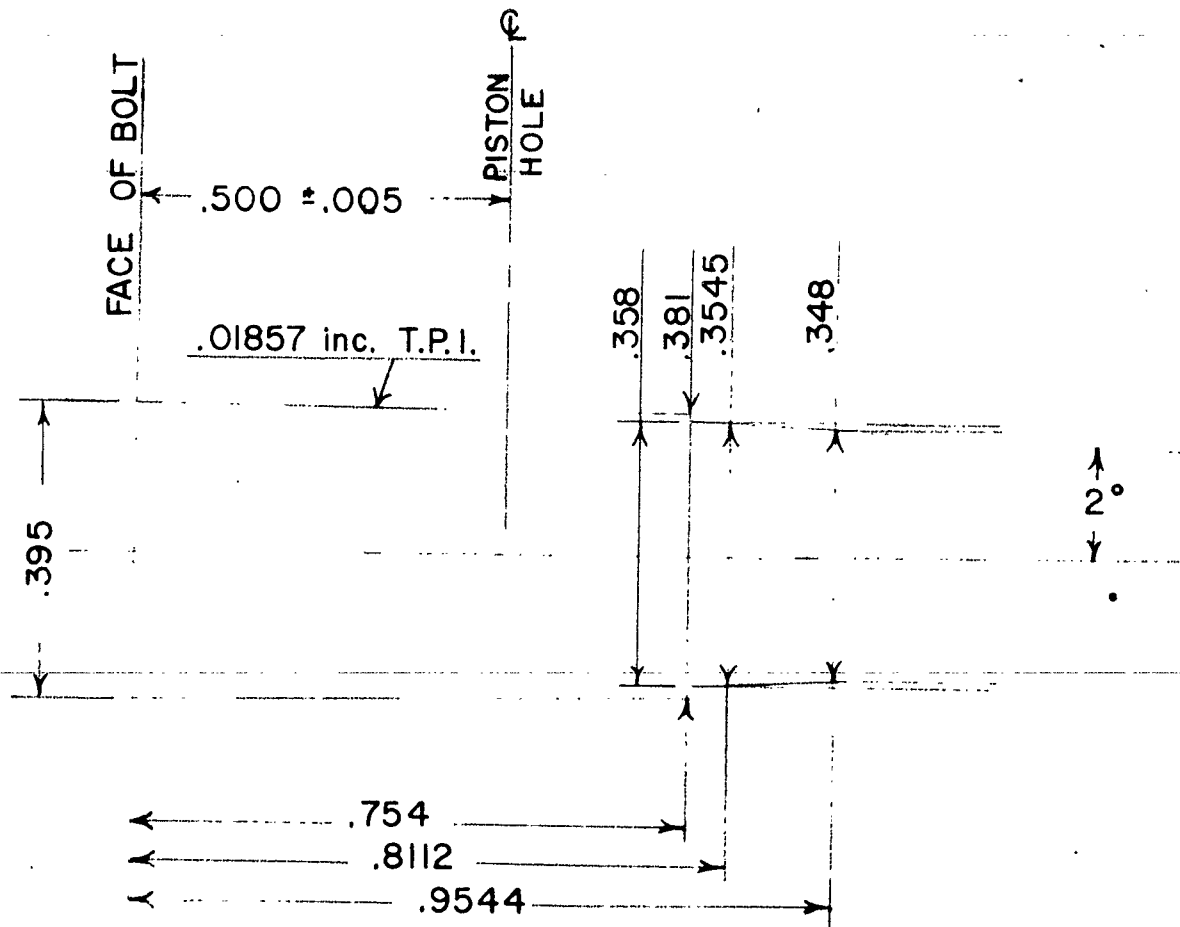
REMINGTON ARMS CO., INC., - BPT., CONN.
RESEARCH & DEVELOPMENT DEPT.

BULLET FOR CARTRIDGE, BALL,
CALIBER .35 T-117-E-1

DRAWN *R. H. E.* APP'D *R. H. E.* DATE *7/15/55*

SKRL- 7-1755-1

EXHIBIT 3



ALL TOLERANCES +.0005 EXCEPT AS OTHERWISE GIVEN

LAND & GROOVE DIMENSIONS TO BE WITHIN TOLERANCES THROUGHOUT

BORE DIAMETER .3480

TWIST 10" R.H.

GROOVE DIAMETER .3580

LENGTH OF BARREL 4"

NO. OF GROOVES 6

DIAM. OF PISTON .206

WIDTH OF GROOVES .120 +.002

REMINGTON ARMS CO., INC., — BPT., CONN.
RESEARCH & DEVELOPMENT DEPT.

STANDARD BARREL FOR
CTG., BALL, CAL. .35 T-117-E-1

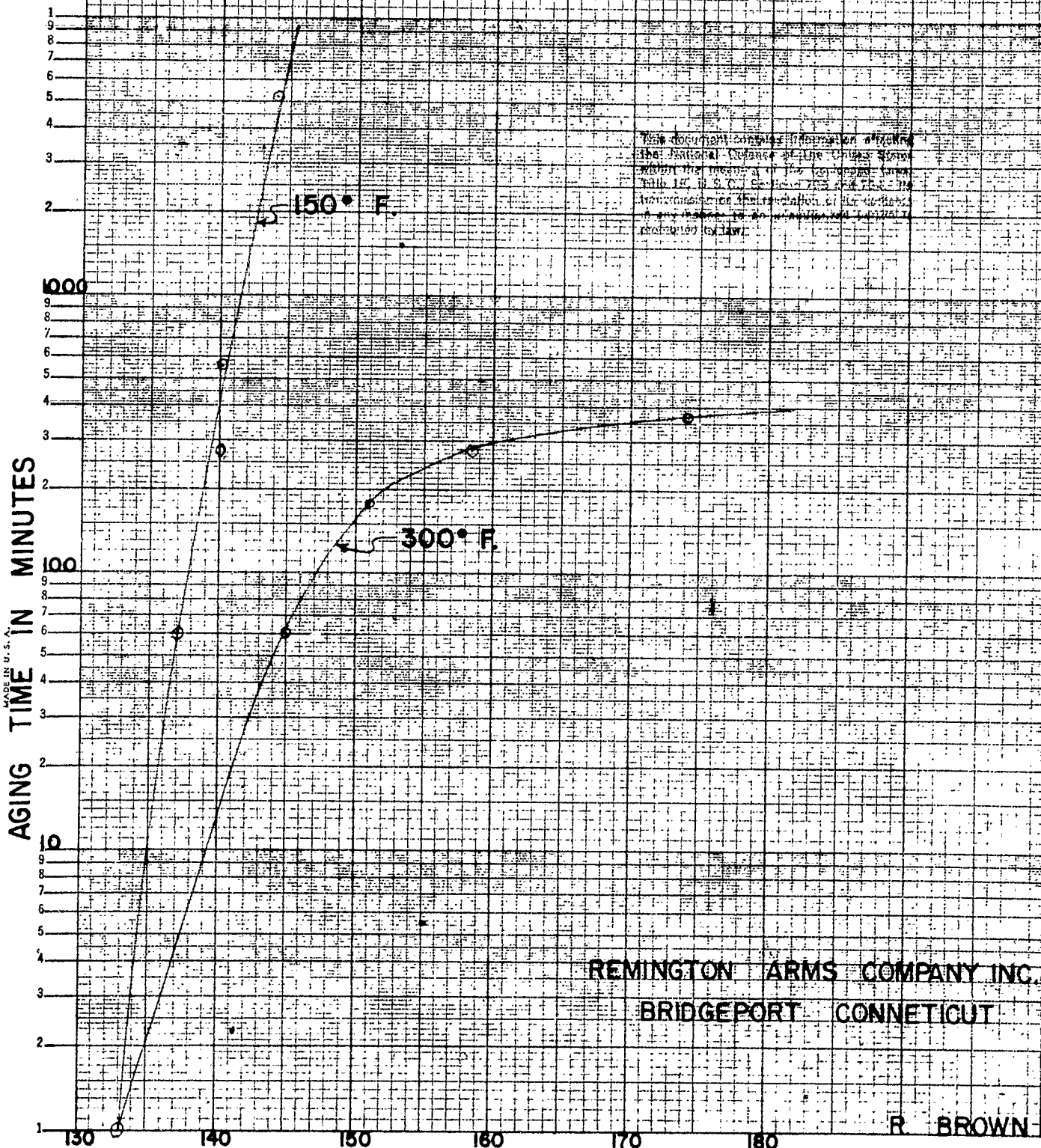
DRAWN R.A.B. APP'D R.A.B. DATE 7/14/35

SKRL-7117-E-1

EXHIBIT 4

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THE EFFECT OF SIZING ON THE DIAMOND PYRAMID HARDNESS
OF DECARBURIZED SAE NO. 1113 STEEL
AGED AT ELEVATED TEMPERATURE



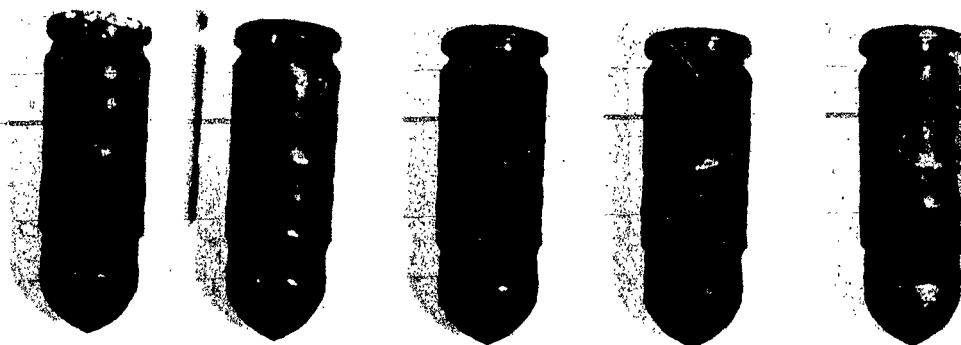
This document contains information affecting the National Defense of the United States within the meaning of the Espionage Laws, Title 18, U.S.C., Sections 793 and 794, the transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

REMINGTON ARMS COMPANY INC.
BRIDGEPORT CONNECTICUT

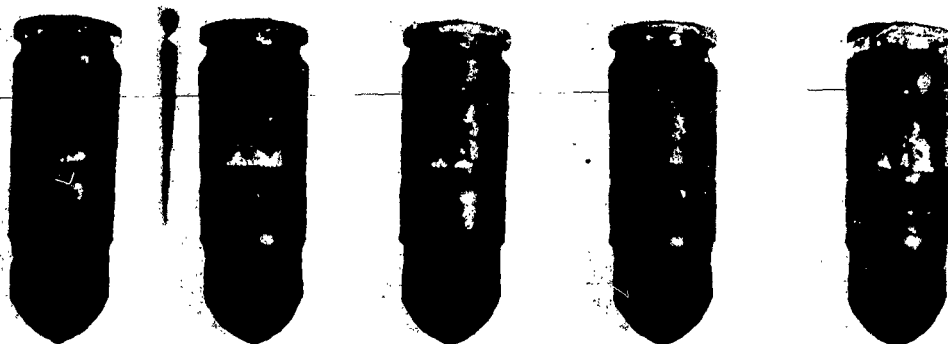
R. BROWN

EXHIBIT 5

AFTER 20 HOURS IN SALT SPRAY ATMOSPHERE



BULLETS INCORPORATING NICKEL PLATING

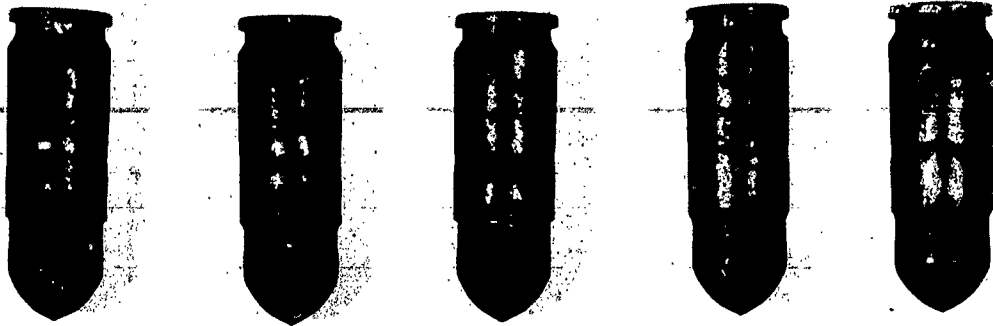


BULLETS WITHOUT NICKEL PLATING

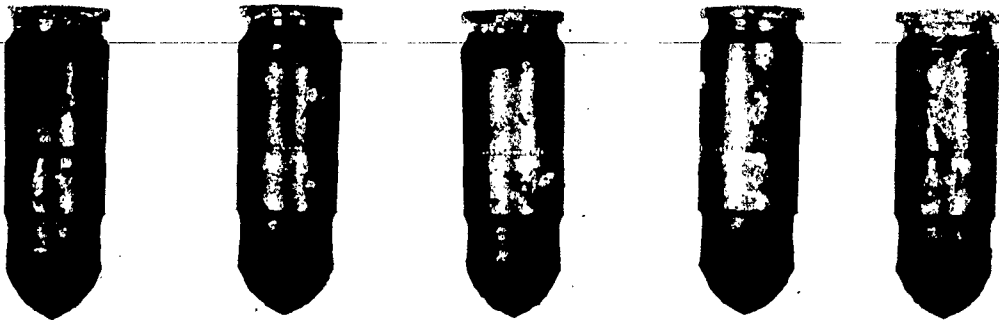


UNPROTECTED STEEL BULLETS

AFTER 70 HOURS IN SALT SPRAY ATMOSPHERE



BULLETS INCORPORATING NICKEL PLATING



BULLETS WITHOUT NICKEL PLATING



UNPROTECTED STEEL BULLETS

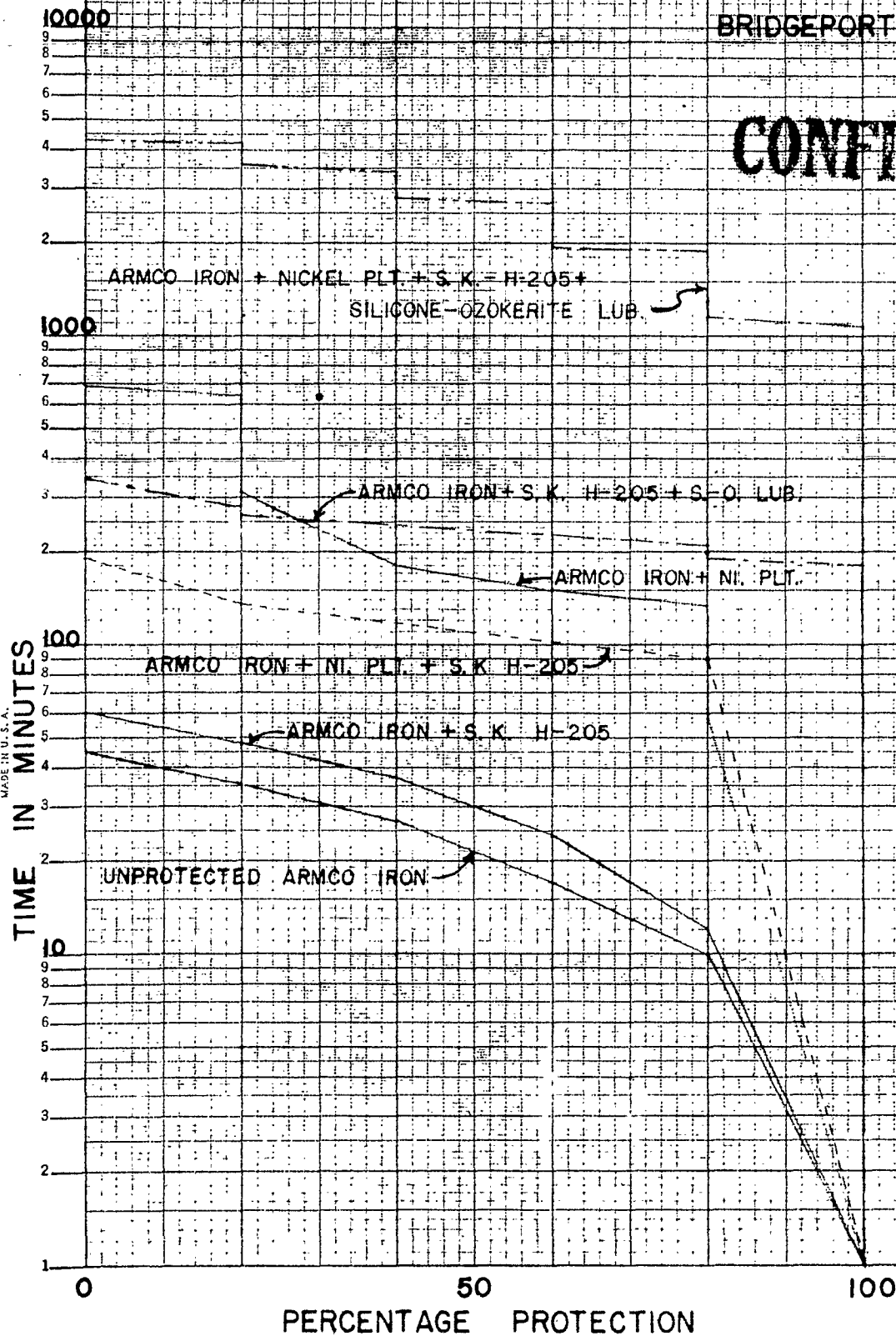
EXHIBIT 6

SALT SPRAY RESISTANCE OF SEVERAL BULLET FINISHES ATMOSPHERE-18-22% BRINE FOG AT 93-98°F.

REMINGTON ARMS COMPANY INC.

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EXHIBIT 7

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BULLET HARDNESS VS ACCURACY AT 25 YARDS
TYPE 14 ARMCO IRON BULLETS
NO SURFACE FINISH

DIAMOND PYRAMID HARDNESS IN Kg./sq.mm.

GROUP SIZE IN INCHES

REMINGTON ARMS COMPANY INC.
BRIDGEPORT CONNETICUT

R. BROWN

D-B-7-1555-3

-JGENT -TZGE -J
MADE IN U. S. A.

NO 340 -10 DIEZIGEN GRAPH PAPER
10 X 10 PER INCH

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100

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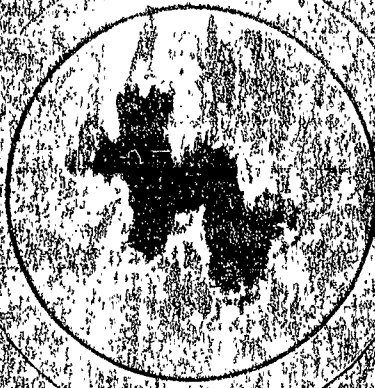
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2.0

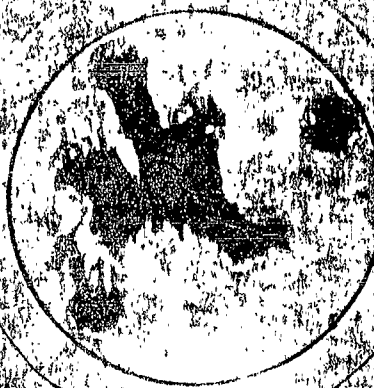
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3.0

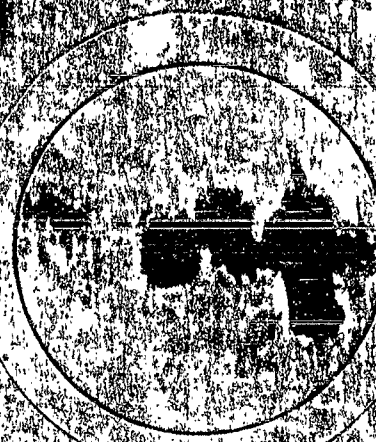
EXHIBIT 8



1.10"



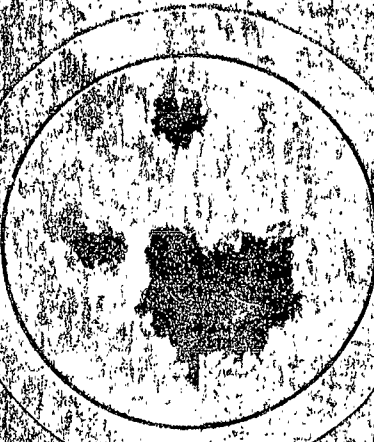
1.65"



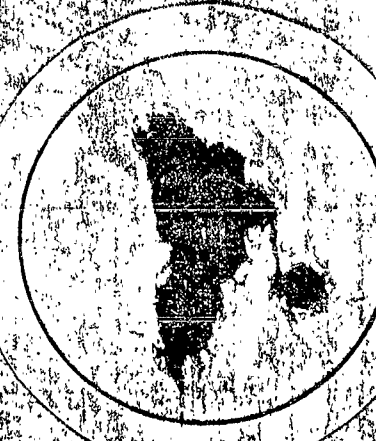
1.70"



1.30"



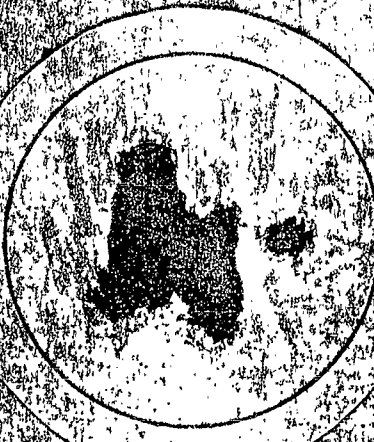
1.35"



1.25"



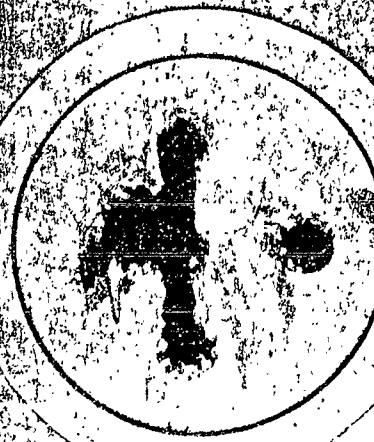
1.63"



1.08"



1.20"



1.15"

ACCURACY OF CARTRIDGE, BALL, CALIBER .35 T-117-E-1

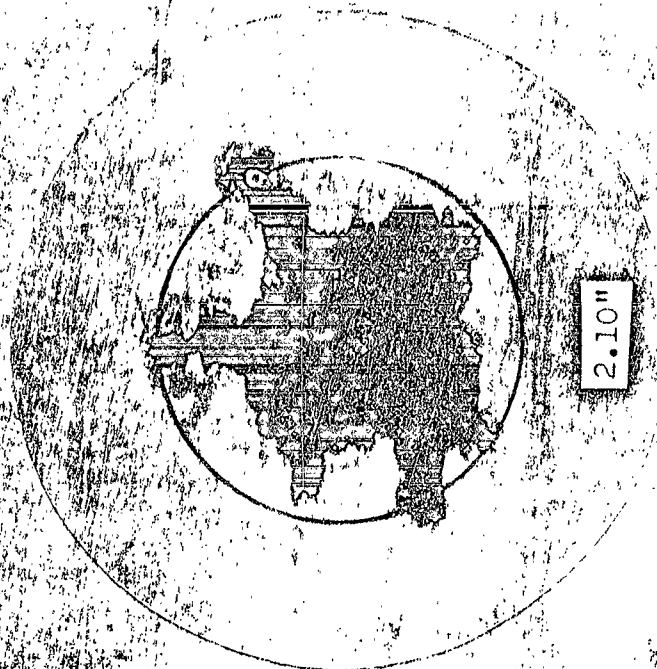
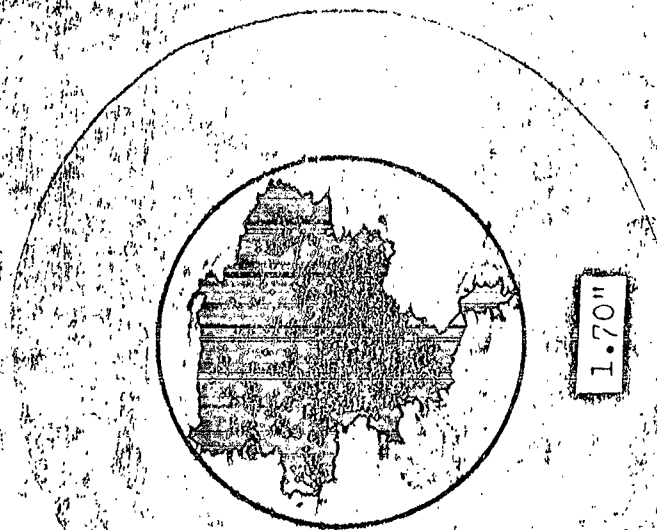
TEN TEN-SHOT TARGETS FIRED AT 25 YARDS

AVERAGE GROUP SIZE -- 1.34"

BARREL TWIST one turn in 10"

BARREL LENGTH 4 inches

EXHIBIT 9



1.70"

2.10"

ACCURACY OF CARTRIDGE, BALL, CALIBER .35 T-117-E-1

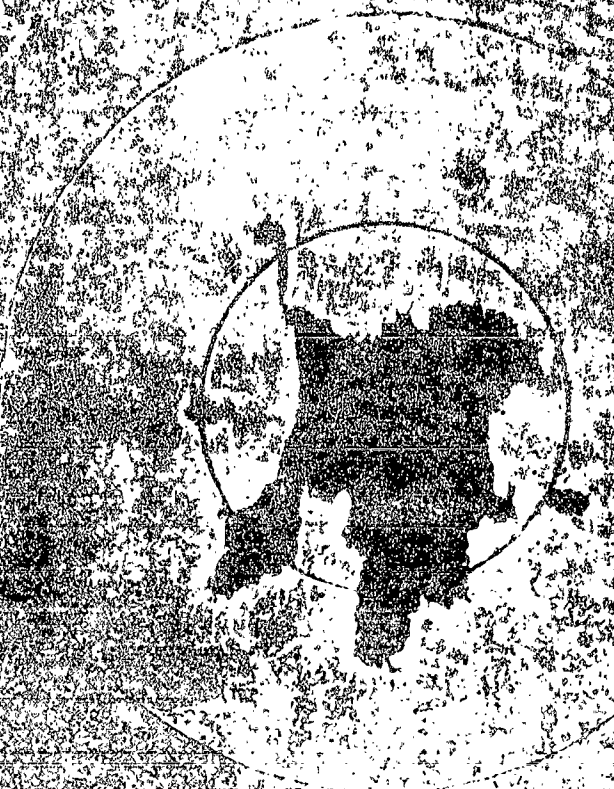
TWO FIFTY SHOT TARGETS FIRED AT 25 YARDS

AVERAGE GROUP SIZE-1.90"

BARREL TWIST one turn in 10"

BARREL LENGTH 4 inches

EXHIBIT 10



BARREL LENGTH 4 inches

9mm PARABELLUM

TYPE FIRE AT 25 YARDS

BARREL TWIST 1:10

EXHIBIT II

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REPORT ON .35 CAL. BALL, CARTRIDGE T-117-E-1

Wound ballistics measurements have been made on 20% gelatin tissue models (cylinders 12.4 cm. in diameter and 12.0 cm. long) with the cal. .35 Ball, Cartridge T-117-E-1. Microsecond roentgenograms were taken of temporary cavities formed by individual bullets at time delays of 250 to 4000 microseconds after impacts of the missiles on the surfaces of the targets.

The velocity of each bullet fired was measured on a 10 ft. baseline using printed silver circuit screens and Potter counter chronographs. The distance from the gun muzzle to the midpoint of the chronograph baseline was 15 ft. 7 in. and the distance from gun muzzle to the surface of the target was 10 yd.

The barrel used was the one provided by Remington: .35 cal., 4 in. barrel, with a 1 in 10 in. rifling twist. It was fired from a fixed mount with a Universal receiver.

The average velocity of 32 bullets fired was 1291 ft./sec., with a standard deviation of plus or minus 12.8 ft./sec. and a standard error of the mean of plus or minus 2.26 ft./sec.

The maximum temporary cavity volume produced by this bullet at 10 yd. range and 1291 ft./sec. muzzle velocity was 303 cc., corrected to 10°C. The maximum value occurred at about 1800 microseconds after the bullet struck the surface of the target. All the bullets were stable during their passage through the targets; no indication of tumbling in the 12 cm. of gelatin was seen.

Copy 1 of 3 copies

1

Regarding data cannot be predetermined.

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ML 7-81-(55)-C

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This value of 303 cc. compares very favorably with the value of 130 cc. for the maximum temporary cavity volume produced by the .45 cal. pistol ball, M1911, at 10 yd. range and muzzle velocity of 836 ft./sec. With the .45 cal. ball, the maximum value came at 1500 microseconds after impact of the bullet on the target surface.

Rough estimates (strictly tentative) can be made for the maximum temporary cavity volumes for lower velocities of the .35 cal. ball, based on previous work with other bullets.

Velocity ft./sec.	.35 cal. Approx. Max. Temp. Cavity Vol. cc.	.45 cal. Max. Temp. Cavity Vol. cc.
1000	160	220
800	90	122
600	43	57

A series of ten 8 mm. Fastax high speed movies (16,000 frames/sec.) were taken of the bullets perforating blocks of 20% gelatin 15 in. x 6 in. x 5 in. in size. However, the films have not as yet been returned by the processors.

This document contains information affecting the national defense of the United States within the meaning of the Espionage LAWS, Title 18 U.S.C. section 793 and 794, as amended. The transmission or the revelation of its contents in any manner to any unauthorized person is prohibited by law.

EXHIBIT 12

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~~BRIDGEPORT~~ ~~CONNECTICUT~~ ~~BRIDGE~~
~~CARTRIDGE~~ ~~BRIDGE~~ ~~BRIDGE~~

11/15

11/16

THRESHOLD OF PENETRATION

11/17

11/18

11/19

11/20

REMINGTON ARMS COMPANY INC
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11/21

11/22

11/23

11/24

100

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CALCULATED VELOCITY VS RANGE
CARTRIDGE, BALL, CALIBER 35

T-117-E-1

THIS GRAPH IS FOR THE PURPOSE OF DETERMINING THE RANGE OF THE CARTRIDGE BALL WITH A GIVEN VELOCITY. IT IS NOT TO BE USED TO DETERMINE THE VELOCITY OF A CARTRIDGE BALL AT A GIVEN RANGE. FOR THIS PURPOSE, SEE THE REMINGTON ARMS COMPANY INC. BRIDGEPORT, CONNECTICUT.

1400

1200

1000

800

600

400

200

0

THRESHOLD OF PENETRATION
OF M-1 HELMET

REMINGTON ARMS COMPANY INC.
BRIDGEPORT CONNECTICUT

R. BROWN

RANGE IN YARDS

25

50

75

100

VELOCITY
10 X 10 PER INCH

NO. 340-10 DIETZEN GRAPH PAT. N

EUGENE DIETZEN CO.
MADE IN U. S. A.

EXHIBIT 13

DOW CORNING

Silicone Notes

DOW CORNING CORPORATION, MIDLAND, MICHIGAN

Preliminary Data

REFERENCE:	3-305
DATE:	January 1955
SUPERSEDES:	
SUBJECT:	Dow Corning F-4050 Fluid Properties and Applications

DOW CORNING F-4050 FLUID

Dow Corning F-4050 is the first of an entirely new class of heat-stable silicone fluids especially adapted for the lubrication of ferrous metal combinations.

This versatile fluid was first developed as an aircraft gas turbine lubricant. Extreme operating conditions of turbo jet engines require a fluid that has good lubricating properties, is pumpable at -65 F, and remains stable at extremely high operating temperatures. Of many fluids evaluated, Dow Corning F-4050 best meets these rigid requirements.

Laboratory tests indicate that Dow Corning F-4050 provides good lubricity for many metal combinations, including steel against steel. For example, Dow Corning F-4050 and other standard silicone fluids were tested in a Falex tester for 30 minutes at a 500 pound jaw load with steel against steel. Dow Corning F-4050 showed no signs of welding and a wear of only 50 to 100 teeth. All other silicone fluids tested with the same metal combination showed excessive wear well below this load and welded at less than 300 pounds load.

Other tests in a Shell 4-ball EP tester further indicate the exceptional lubricating properties of Dow Corning F-4050 Fluid. These tests gave an incipient seizure load of 80 kilograms and a weld point of 100 kilograms for Dow Corning F-4050. A typical diester type lubricant had an incipient seizure load of 70 kilograms and a weld point of 120 kilograms.

TYPICAL PROPERTIES

Color	Water white
Viscosity, centistokes	
at -65 F	43,000
at 77 F	21
at 100 F	16
at 210 F	5
Freezing Point, degrees Centigrade, below	-75
Flash Point, degrees Fahrenheit, approximately	400
Specific Gravity at 25 C	1.04
Refractive Index at 25 C	1.48
Shipping Weight, pounds per gallon	8.5

BRANCH OFFICES

ATLANTA, 1343 Spring St., N. W. • CHICAGO 1, 228 N. LaSalle St. • CLEVELAND 13, 2215 Terminal Tower • DALLAS 26, 2722 Taylor St.
DETROIT 24, 16640 East Warren Ave. • LOS ANGELES 15, 1514 S. Hope St. • NEW YORK 20, 600 Fifth Ave.
WASHINGTON, D. C. (Silver Spring, Md., 8561 Fenton St.)

DOW CORNING SILICONES are also available in: CANADA, Dow Corning Silicones Ltd., Tippet Road, Wilson Heights, Toronto, Ontario;
ENGLAND, Midland Silicones Ltd., 19 Upper Brook St., London, W. 1; FRANCE, St. Gobain, Chauny et Cirey, 1 bis, Place des Saussoies, Paris (8°),
and through distributors in Australia, Belgium, Denmark, Germany, Holland, Italy, Japan, Mexico, Norway, South Africa, Sweden and Switzerland



DEPARTMENT OF THE ARMY
US ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND
ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
PICATINNY, NEW JERSEY 07806-5000

RDAR-MEM

4 November 2010

MEMORANDUM FOR Mr. Lawrence Downing, Information Security Officer, Defense
Technical Information Center, DTIC-OQ, 8725 John J. Kingman Road, Fort Belvoir, VA 22060

SUBJECT: Change in Distribution Limitation/Classification of Document

1. This office has reviewed the technical report "(U) RESEARCH, DEVELOPMENT
AND FABRICATION OF CARTRIDGE, BALL, CALIBER .35 T-117-E-1", Accession
Number: AD0071619, Report Date: 26 July 1955, per your email request of 21 October 2010,
and has determined that the distribution statement should be changed as follows:

FROM: "Distribution authorized to U.S. Government agencies and their contractors;
Administrative/Operational Use; 26 JUL 1955. Other requests shall be referred to Frankford
Arsenal, Philadelphia, PA"

TO: "APPROVED FOR PUBLIC RELEASE"

2. The reason for the change is that the technology cited in this document is obsolete and no
longer needs to be protected. Date of this change is today, 4 November 2010.

3. Should you have any further questions or require additional information regarding this
matter, contact Mr. Ralph Mazeski by phone, 973-724-6453, or send email to
ralph.mazeski@us.army.mil.

ERNEST L. LOGSDON
Director, Munitions Systems & Technology Directorate